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Final report relating to research carried out under  
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This is a summary of the research completed under AASERT grant F49620-97-1-0482, during the period September 1, 1997 to August 31, 2000.

Not long ago it was shown that the spectrum of light scattered off of a system of particles will be altered by the spatial correlation properties of the particle system. Such a result implies that the spectral changes of the scattered light contains information about the structure of the particle system. We have since demonstrated that the spectral information can be used in the inverse problem of particle-system structure to drastically reduce the amount of data required for inversion [1], by substituting spectral measurements for measurements in different directions. These results were presented at the 1999 Optical Society of America Annual Meeting in Santa Clara, California.

The nonuniqueness of inverse source problems, in both the deterministic and statistical problems, has been known for quite some time. This nonuniqueness is a consequence of the existence of so-called nonradiating sources which do not produce any field outside the source domain. In the statistical source problem, this implies some quite nonintuitive radiation effects. In earlier work,

we demonstrated that sources which are spatially fairly incoherent can produce fields that are completely coherent outside the source domain. We have now demonstrated that electromagnetic sources which are effectively unpolarized may produce nearly perfectly polarized electromagnetic fields outside the source domain [2].

Nonradiating source distributions are spatially quite complicated and have not, as yet, been directly measured. Such distributions will most likely be first found in simpler, one dimensional source problems. Following earlier work by our group, we have investigated nonpropagating string excitations, i.e. vibrations on a string which do not propagate away from the region of the applied force, under circumstances which will arise in any experimental setup. We studied the existence of such localized vibrations on a string with finite, fixed ends, with damping, and with a finite bandwidth driving force [3]. It was found that even under these circumstances, the effects of nonpropagating modes will be significant and observable.

In recent years, the technique of phase conjugation has gained much popularity because of its ability to correct distortions in light waves transmitted through inhomogeneous media in a double-pass configuration. Such corrections have been shown to be of interest in correcting atmospheric distortion, among other uses. The theory of distortion correction for scattering from deterministic media has been known for quite some time; however, little research has been done into the effectiveness of phase conjugation for correction of distortions caused by spatially random media, or for correction of distortions imparted upon a partially coherent incident field. We have demonstrated that a phase conjugate mirror can correct for distortions caused by spatially random media, and for distortions imparted upon a partially coherent field [4]. These results were presented at the 1998 Optical Society of America Annual Meeting in Baltimore, Maryland.

For some years now the characterization of laser beam "quality" has been of interest to scientists and engineers. Methods involving moments of the beam

intensity in the near and far zone have been in use (and debated) for some time. In our first publication on the subject [5], our group derived criteria for the moments of a laser beam to exist in the far zone of the beam waist, and developed a method to optimize arbitrary products of even moments in the far zone. Our more recent work [6] has generalized these optimization methods to cover products of both near and far zone moments. We have applied this generalization to analyze the properties of the most often used measure of beam "quality", the so-called beam quality (or propagation) factor  $M^2$ . We have demonstrated that optimization of this factor requires the specification of further characteristics of the beam, and that, therefore, the  $M^2$  factor by itself is an incomplete description of the propagation of the beam.

It is now a well-known fact that the spectrum of light produced by a partially coherent source may differ from the spectrum of the source that generated it, and may in fact change on propagation. These correlation-induced spectral changes have been the subject of much research and controversy since their introduction. An early criticism of such changes was that they seemed to violate energy conservation. Earlier work by our group demonstrated that correlation-induced changes were consistent with energy conservation for scalar radiation fields, and we derived a new conservation law which was convenient for the study of such phenomena. As part of our research under the AASERT grant, we have since derived a new energy conservation law for random *electromagnetic* radiation sources, which demonstrates the consistency of correlation-induced changes with energy conservation for electromagnetic fields [7]. These results were presented at the 1997 Optical Society of America Annual Meeting in Long Beach, California.

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